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ABSTRACT

Based on a review of American literature and interviews with Chinese elementary mathematics teachers, a survey of elementary mathematics teachers' beliefs about mathematics and mathematics teaching was developed. The responses of 66 American and 92 Chinese elementary mathematics teachers were examined. Significant group differences were found in the following areas: (1) personal discovery versus restricted instruction, (2) solving real world problems versus laying a foundation for further mathematics learning, (3) parental involvement in children's mathematics learning, (4) use of computational devices, and (5) teachers' beliefs about the importance of three kinds of professional knowledge--mathematics subject knowledge, pedagogical knowledge about how to teach mathematics and the knowledge about understanding children. The findings are interpreted with regards to culturally related metacognitions that may influence mathematics teaching and learning. (Contains 53 references.) (Author/MM)

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Comparing American and Chinese Elementary Mathematics Teachers' Beliefs about Mathematics and Mathematics Teaching

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Abstract

Based on a review of American literature and interviews with Chinese elementary mathematics teachers, a survey of elementary mathematics teachers' beliefs about mathematics and mathematics teaching was developed. The responses of 66 American- and 92 Chinese elementary mathematics teachers were examined. Significant group differences were found in the following areas: (1) personal discovery versus restricted instruction, (2) solving real world problems versus laying a foundation for further mathematics learning, (3) parental involvement in children's mathematics learning, (4) use of computational devices, and (5) teachers' beliefs about the importance of three kinds of professional knowledge – mathematics subject knowledge, pedagogical knowledge about how to teach mathematics and the knowledge about understanding children. The findings are interpreted with regards to culturally related metacognitions that may influence mathematics teaching and learning.

Comparing American and Chinese Elementary Mathematics Teachers' Beliefs about Mathematics and Mathematics Teaching*

Cross-national research on mathematics achievement has consistently reported superior performance by Asian students over American students (e. g., Hess, Chang & McDevitt, 1987; Huntsinger, 1996; Husen, 1967; Stanley, Huang & Zhu, 1986; Stevenson, et al., 1990; Stigler, et al., 1982). Motivated by the desire to improve American students' mathematics achievement, attempts at understanding these differences have been the focus of several studies (e.g., Huntsinger & Jose, 1997; Lynn, 1991 &1997; Miura, 1987; Nelson, 1982; Stevenson, et al., 1990; Stevenson & Stigler, 1992; Stigler & Hiebert, 1997; Stigler, Lee, & Stevenson, 1990). Stevenson (1990) and his colleagues, in collaboration with Chinese scholars, initiated a large-scale cross-cultural study of mathematics achievement in China and the United States. The results of the study have shown that the superior performance of Chinese students over their American peers was related to mothers and children's beliefs about effort and ability, after school activities, homework and longer school days. Huntsinger and Jose (1996) reported that Chinese children spent more time on mathematics homework, and Chinese parents used more systematic formal methods of mathematics teaching than American parents. Stigler and his colleagues (1982) compared the contents of mathematics textbooks (Grade 1 to 6) from three countries, Japan, Taiwan and the United States. They concluded that the level of achievement in elementary school mathematics was related to classroom instruction, not to the content of the curriculum. In another study, Stigler and his colleagues (1987) commented, " Instruction is an essential component to learn the complex material in the mathematics curriculum".

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Investigation of mathematics instruction in elementary and secondary education has traditionally considered the effects of teaching practices (Koebler, 1992), teachers' knowledge and its impact (Fennema, 1992) and instructional methods (Good, 1992). Since the 1970s, research interest has gradually shifted from teaching behaviors to a focus on teachers' thinking and decision-making (Thompson, 1992), the effect of metacognition (Garofalo, & Lester, 1985), teacher efficacy (Giberson, & Dembo, 1984; Kelly, 1987), teachers' attitudes toward mathematics teaching and other affective factors (McLeod, 1992) and teachers' beliefs about the nature of mathematics and mathematics problem solving (Kloosterman & Stage, 1992; Thompson, 1984). There is a growing interest in the study of the impact of teachers' beliefs about their classroom practice. Although a number of studies highlight the discrepancies between teachers' espoused beliefs and observed classroom practices (e.g., Galton, Simon, & Croll, 1980), many studies have identified an association between teacher's beliefs and their perceptions of the situation in their classroom (e.g., Brown & Rose, 1995; Nespor, 1987; Short & Short, 1989). Numerous case studies have reported consistencies between teacher's beliefs about their subject or about teaching and learning and the way in which they plan their work, teach in the classroom and their evaluation of students' learning outcomes (Cornett, 1990; Cornett et al., 1990; Wilson & Wineburg, 1988). Brown and Rose (1995) found that obstacles to the use of instructional strategies coincide with teachers' beliefs. Nespor (1987) pointed out that beliefs have great value in dealing with complex, ill-defined situations. Teacher's beliefs help to interpret and simplify classroom life, to identify relevant goals and to orient teachers to particular problem situations.

Among cross-national studies, research on mathematics education has been more plentiful than research on any other academic subject. Most of these studies examined the students'

family factors or school environment that affected students' mathematics achievement. Clearly, parents' beliefs and attitudes about children's academic performance and the way they train their children have a great influence on children's academic achievement. It is also true that time and effort is related to achievement in mathematics. However, students' acquisition of academic knowledge comes primarily through formal education. In general, teachers play a more important role in the development of students' academic knowledge than do parents. It is, therefore, important to understand the possible influence of teachers' instructional beliefs and methods that would result in differences in mathematics performance between Chinese and American students.

There have been few cross-cultural studies of classroom instruction. Among them, the most distinguished is the Third International Mathematics and Science Study (TIMSS). Stigler and his colleagues (1998) have analyzed videotaped portions of TIMSS data, and reported on the "typical" mathematics instruction in Germany, Japan and the United States (Stigler, et al., 1999; Stigler & Hiebert 1998; Stigler & Hiebert 1997). They suggested that while the lesson patterns of the United States and Germany were similar, they differed from that of Japan (Stigler et al., 1999, pp.159-160). US and German lessons follow an acquisition/application script. During the acquisition phase, students are expected to learn how to solve particular types of problems, often through watching demonstrations by the teacher or their peers. During the application phase, students are expected to practice what they have learned. The lesson pattern in Japan might be called a "problematizing" script. In this script, problems play a very different role. Rather than problem solution serving as the goal of the lesson, they are the means through which students are to understand properties or principles of mathematics. Through use of TIMSS data, Philippou and Christou (1999) studied teachers view about mathematics. They

found that teachers from four high-achieving Asian countries were more likely to see mathematics as algorithmic than were teachers from four European countries.

However, cross-cultural investigations about teacher related factors, such as teachers' beliefs about the nature of mathematics, how to teach mathematics and teachers' knowledge structures go largely unexamined. We believe that a comparative study of mathematics teachers' metacognitions would provide information about cultural effects on cognitive and affective processes related to mathematics instruction and learning.

The current comparative study of elementary mathematics teachers began in the fall of 1998. Data collection was completed in the fall of 2000. Cross-cultural differences in teachers' beliefs about the nature of mathematics, how to teach elementary mathematics and their mathematical and pedagogical knowledge were examined. This paper is the first part of the more extensive report.

Methods

Subject

Ninety-two full-time Chinese elementary mathematics teachers (77 female) from two large cities, Beijing and Shanghai were surveyed in the spring of 1999. The average years of teaching for this group was 12.26 years and the average grade level they taught was 4.40. Sixty-six American elementary mathematics teachers (62 female) were recruited from the Dallas area. Twenty-two responded to the survey in the spring of 2000. They were all full time elementary mathematics teachers. The other forty-four responded in the fall of 2000. Three of the forty-four were not currently full time elementary mathematics teachers – one was a special education teacher, one was a facilitator, and another was a resource teacher. The average

teaching experience of this group was 9.78 years, and the average grade level they taught was 4.18. A chi-square test for gender differences in proportion by country was significant (χ^2 =3.81, df=1, p<0.05). The proportion of male teachers in the Chinese group was higher than that of the American group at a minimum level of significance. The chi-square test of grade-level between the two groups was not significant. Differences in teaching experience between the two groups were examined by means of a t-test. No group difference was found.

Samples were not randomly selected. The subjects are paid for their participation.

Instrument

The first step in developing a cross-cultural measurement instrument of elementary mathematics teachers' beliefs was to collect information about teachers' beliefs in both the United States and China. Beliefs are held in clusters (Green, 1971). To be inclusive of dimensions of elementary mathematics teachers' beliefs, the development of the instrument started with a review of literature about mathematics teachers' beliefs by American and British scholars. In order to assess Chinese teachers' beliefs, two group interviews with Chinese elementary mathematics teachers were conducted – one in Beijing and the other in Shanghai.

According to Calderhead (1996), teachers hold beliefs about learners and learning, about teaching, about the subject, about learning to teaching, about self and the teacher's role in classroom instruction. Ernest (1989b) defines the key components of the mathematics teachers' beliefs as teachers' view of the nature of mathematics, teachers' model of the nature of mathematics teaching and teachers' model of the process of learning mathematics (p.99). Building from these assertions, the survey for this study was constructed in five parts – teachers' view of the nature of mathematics as a subject, teachers' view of the nature of

elementary mathematics as a course, teachers' model about mathematics teaching, teachers' model about mathematics learning and teachers' conception about their knowledge structure.

The various schools of thought in the philosophy of mathematics include Platonism, Logicism, Intuitionism, Formalism, and Constructivism (Dossey, 1992). According to Dossey (1992), there have been two distinct schools, platonic and aristotelian. The platonic view takes a position that the objects of mathematics have an existence of their own, beyond mind, in the external world. The aristotelian view of mathematics is based on experienced reality, where mathematics knowledge is obtained through mathematicians' experimentation, observation, and abstraction. Logicism is an outgrowth of platonic view. The common notion of Platonism and Logicism is a product orientation with a concern about objectivity of mathematical existence or truth. Dossey (1992) labeled this type of thought as "external conceptions" of mathematics. In contrast, Intuitionism, Formalism, and Constructivism have their roots in the aristotelian view. These approaches view mathematics as a process. Knowing mathematics is equated with doing mathematics. Dossey (1992) calls this view "internal conceptions" of mathematics. Both major approaches were considered in the construction of the survey used in this study. Ernest (1989a) points out that, in recent years, mathematics teachers in the developed countries have been bombarded with official reports and recommendations stressing the importance of the process aspects of mathematics. In response to these recommendations, mathematics teachers in these countries are increasingly espousing a process-oriented view of mathematics, focusing upon the students' individual discovery of mathematics knowledge. This modern constructivism view was also a consideration in the development of our measurement instrument.

Kuhs and Ball (1986) have identified "at least four dominant and distinctive views of how mathematics should be taught" (p. 2). The first is the learner-focused view. From this view, the

teacher is a facilitator and stimulator of student learning. The second is a content focused view with an emphasis on conceptual understanding. Teachers who hold this view would emphasize mathematical content in classroom activities. They would be more likely to focus their teaching on students' understanding of the logical relations among various mathematical ideas and the logic underlying mathematical procedures. The third is the content focused view with an emphasis on performance. From this perspective, the teacher's role is to demonstrate, define, explain and present in an expository style. The student's role is as a listener. Finally there is the classroom-focused view. Central to this view is the notation that classroom activities must be well structured and efficiently organized.

From interviews with Chinese elementary mathematics teachers, we found that their conceptions about elementary mathematics learning are composed of four parts – concerns about mathematics learning, homework assignments, the use of computational devices and the relationship between parental factors and children's achievement. Fennema (1992) has discussed mathematics teachers' context specific knowledge. According to her model, mathematics teachers' knowledge includes three components: knowledge of mathematics, knowledge of learners' cognition in leaning mathematics and knowledge of pedagogy. These observations informed in the survey instrument. The detailed framework of the instrument is provided in Table 1. Teachers' beliefs are organized in five clusters, and each cluster is composed of its component parts and the items used to assess the component.

(Insert Table 1)

In writing survey items, we reviewed the instruments from other studies of teachers' beliefs (such as Cooney, T.J., Barry, E.S., & Bridget, A., 1998; Jehng, Johnson, & Anderson, 1993; Jacobson, Jehng, & Maouri, 1996). A few items were adapted from these instruments. In

our instrument, however, most items were developed from literature published by American and British scholars and from the interviews with Chinese teachers. The survey was first written in English. The Chinese version was translated from the English version with a cross-translation to insure common meanings in English and Chinese. The total number of items in this survey is forty-three. Items 1 to 37 are likert-type items. In order to force subjects to make either positive or negative choices, these items have only four choices – "true", "somewhat true", "somewhat false" and "false". They are subjective to validation procedures. Items 38 to 42 use a multiple-choice format. These items ask for detailed information, such as "at which grade do students need to have homework assignments'" or "at which grade can students be allowed to use calculators", rather than general perspectives. Item number 43 is a ranking question about the importance of three kinds of knowledge, common to mathematics teachers. The full survey is attached.

The divergent nature of human beliefs about mathematics, mathematics instruction and learning resulted in wide variation in item content. This heterogeneity of item content increased the difficulty in the validating the instrument. Content validation was undertaken through experts' evaluations. Four professors of psychology and one professor of Special Education were invited as judges. They were provided with short statements descriptive of the construct of each cluster. Using these statements, they sorted the items into the specified categories. The percentages of the judges' agreement in matching items to cluster descriptions were taken as index of the content validity. If three or more of the five raters (60% or more) failed to agree, the item was dropped. If all five raters (100%) agreed that an item needed to be classified into another category, the item was moved to the new category. The percentages of judges' agreement on matching items to cluster descriptions are reported in Table 2. Simple

construction validation was obtained through correlations among cluster scores, and the correlations between cluster scores with the total score (see Table 3). Low correlation coefficients among five clusters indicated that clusters address different constructs. Difficulties with subject availability prevented us from using test-retest reliability. The internal-consistency of the questionnaire was obtained through three methods, correlations between item scores and the cluster scores (total score of items in this cluster), correlations between item scores and the total score (entire survey), and correlations between cluster scores and the total score. The results are reported in Table 2 and Table 3.

(Insert Table 2 and Table 3)

Results

To gain maximum insight into the differences between the two groups, data analyses were based on individual items, rather than the clusters. Due to the all-inclusive nature of the instrument, the report of the study is complicated. For ease of comprehension, the results are reported by cluster followed by a summary. Group differences were examined by means of the Mann-Whitney rank test. Significant group differences were found for 22 of the 43 items.

Cluster 1: Teachers' Conceptions about the Nature of Mathematics as a Subject

Items 1, 2, 3, 27 and 28 were designed to measure this construct. Item 1 represents a platonic view, or external view; items 2 and 3 represent an aristotelian view, or internal view (see Appendix). No significant group differences were found in these items. The high percentages of "true" and "somewhat true" choices on these items in both American and Chinese groups implied that the traditional views have strong influence worldwide. The

correlation between item 2 and 3 was small but significant ($r=0.25$, $p<0.01$), whereas the correlation coefficients between items 1 and 2, and items 1 and 3 were near zero. Since no significant negative correlations were found, there was no clear evidence that teachers who prefer the external view would hold an adverse attitude toward the internal view, and vice versa. Dossey (1992) has surveyed the American literature concerning mathematicians' conception of the nature of mathematics and concluded that their conceptions of mathematics fall along an externally-internally developed continuum. This seems to be true for elementary mathematics teachers, both American and Chinese.

Items 27 and 28 represented a modern constructive view. Group differences for these two items were significant ($Z=2.687$, $p<0.01$ for item 27, and $Z=4.929$, $p<0.001$ for item 28). Most American teachers strongly agreed with "*Teenagers can discover (or create) something of mathematics by themselves*" (item 27) and "*Real mathematics problems can be solved by common sense instead of mathematics rules you've learned in school*" (item 28). But most Chinese teachers did not agree. The correlation between items 27 and 28 was significant ($r=0.31$, $p<0.001$), but the correlations of these two items with items 2, and 3 were all near zero. Although it is considered by some scholars (Dossey, 1992) that both the modern constructive view and the internal view shared similar roots, the near zero correlations suggest that the two views were not related. A careful reading of the meaning of word "mathematics" in these four items suggests alternative meanings. The meaning of "mathematics" in items 2 and 3 seems to refer to mathematics subject knowledge, whereas "mathematics" in item 27 seems to refer to the personal knowledge of a student. The American teachers tend to believe that both common and individual mathematics knowledge can be developed through individual discovery. However, while the Chinese teachers appear to believe that mathematics subject

knowledge can develop by mathematicians through discovery, young learners are unable to discover mathematical knowledge by themselves.

Cluster 2: Teachers' Conceptions about the Nature of Mathematics as a Course

This cluster consists of three parts. The first component, "what is elementary mathematics" involves three items. No significant group differences were found in items 4 and 5, but there was a significant group difference in item 6 ($Z=3.233$, $p<0.001$). A large percentage of Chinese teachers agreed with these three items (see Appendix). For the American group, a large percentage endorsed "true" and "somewhat true" to items 4 and 5, but no so to item 6. This indicated that many Chinese elementary teachers believe that elementary mathematics can be learned mainly through logical thinking and reasoning, but not many American elementary mathematics teachers concurred. Content similar to item 6 appears in items 9, 19, and 24 (see Appendix). However, no significant group differences were found in these items.

Items 8, 9, and 10 examined teachers' beliefs about the purpose of learning elementary mathematics. Significant group differences were found for items 8 ($Z=4.095$, $p<0.001$) and 10 ($Z= 5.930$, $p<0.001$). Many Chinese teachers agreed that *the purpose of elementary mathematics is to learn basic concepts, principles and skills for further mathematics study* (item 8), but a small percentage of American teachers agreed with this statement. The pattern of the answers to item 10 was reversed. More American teachers than Chinese teachers agreed that *the purpose of elementary mathematics learning is for solving real word problems.* In both American and Chinese groups, most teachers agreed that *mathematics is a kind of mento! exercise, and the goal of elementary mathematics learning is to train logical thinking and reasoning* (item 9).

Seven items (Table 1) asked for a comparison of the characteristics of elementary mathematics and language courses. Significant group differences were found in three items, items 13 ($Z=2.557$, $p<0.05$), 15 ($Z=3.010$, $p<0.01$) and 16 ($Z=3.738$, $p<0.001$). Most American teachers believed *mathematics is drier than English for their students* (item 13) and did not believe that *there were more mathematically precocious children than reading precocious children in their school district* (item 15). Only a few Chinese teachers agreed with item 13. Most of them agreed with item 15. Stanley, Huang & Zhu (1986) reported a high percentage of mathematically precocious youth (SAT-M score above 700), tested at age of thirteen or younger in Shanghai, China. It could be that there is a greater population of mathematically precocious children than reading precocious children in China. Answers to item 16 showed more Chinese teachers than American teachers agreed with the statement "*there are many open-ended questions in elementary mathematics*". However, the answer pattern of Chinese teachers to item 16 was not consistent with pattern to item 7, to which many Chinese teachers agreed, "*Unlike reading comprehension, the mathematics problems in elementary and secondary mathematics classrooms have only one true answer*" (item 7).

Cluster 3: Teachers' Model about Mathematics Teaching

Items 17 to 26 represented four types of teachers' conceptions about mathematics teaching. Group differences were found for items 20 ($Z=3.11$, $p<0.01$), 22 ($Z=2.652$, $p<0.01$) and 25 ($Z=3.295$, $p<0.001$). Item 20 presents a classroom-focused view. Among Chinese teachers, 60% strongly agreed that "*classroom activities must be well structured and effectively organized*", and 26% endorsed "somewhat true". However, for the American group, only 30% of teachers endorsed "true", and 45% agreed "somewhat true". In most Chinese schools, the

classroom is teacher-centered (An, 2000; Ma, 1999). The lessons are planned and followed step by step. It is reasonable that most Chinese teachers endorsed this item statement.

Four items, items 17, 21, 22, and 25, presented a content-focused view with an emphasis on performance. Significant group differences were found for items 22 and 25. More American teachers agreed with "*Good elementary mathematics teachers ask students to learn the right problem solving procedures through classroom practice and homework*" (item 22) and "*Good elementary mathematics teachers show students the exact way to answer mathematics questions on which they will be tested*" (item 25), than did Chinese teachers.

Items 18 and 23 represent the learner-focused view. There were no significant group differences in these two items. Most teachers, whether American or Chinese, responded positively to them. American educational philosophy tends to advocate students-centered classrooms, while Chinese educational philosophy promotes a teacher-centered classroom. In this study, not only many American teachers, but also many Chinese teachers accepted that teachers' role in the classroom is as a facilitator, a stimulator and a motivator of students to discover the right way to respond (see Appendix).

Items 19, 24, and 26 represented the content-focused view with an emphasis on conceptual understanding. No significant group differences were found for these items. Both Chinese and American teachers agreed that "*As an elementary mathematics teacher, I demonstrate, explain, and define the material, but would like to emphasize students' understanding of the logical relations among various mathematical ideas and concepts*" (item 19) and "*Good elementary mathematics teachers emphasize training of logical thinking and reasoning*" (item 24). Like item 6, both statements put an emphasis on students' logical thinking and reasoning.

Cluster 4: Teachers' Model about Mathematics Learning

This cluster involves four parts. Items 29 to 32 are statements about mathematics learning. Significant group differences were found for items 30 ($Z=1.975$, $p<0.05$), 31 ($Z=8.496$, $p<0.001$), and 32 ($Z=3.605$, $p<0.001$). More American than Chinese teachers agreed that "*to solve mathematics problems, you have to be taught the right procedures or you can do nothing*" (item 30). About 86% of American teachers agreed that "*there are mathematics geniuses who can do well in mathematics without hard work*" (item 31), whereas about 86% of Chinese teachers responded "false" and "somewhat false" to this item. More American than Chinese teachers endorsed "*there is no easy way to learn mathematics, the more you practice, the more you accomplish*" (item 32).

Items 33 and 34 are questions about parental factors. Most teachers in both groups agreed with item 34, "*usually, well-educated parents have mathematics talented children*". However, there were significant group differences for item 33 ($Z=6.973$, $p<0.001$). About 77% of American teachers agreed that "*if parents work with their children on mathematics homework and projects, their children could achieve higher marks in mathematics*", whereas about 77% of Chinese teachers disagreed with this statement. Items 38 and 39 are the questions about homework assignment. The patterns of answers to item 38 are almost the same for the two groups. About 40% of teachers in both groups selected 10 to 20 minutes for daily homework time, and about 44% selected 20 to 30 minutes. However, the pattern of the answers to item 39 ($Z=4.109$, $p<0.001$) gave a different picture. About 60% of American teachers thought that pupils should have homework starting from Grade 1, whereas only 14% of Chinese teachers thought so. Twenty-six percent of Chinese teachers selected Grade 2 as the starting grade for homework, while 41% of this group selected Grade 3. This is an interesting finding, because

based upon Huntsinger and Jose's study (1996), we expected that teachers in Asian countries would like to assign more homework and assign homework at an earlier age than American teachers. The results suggest that the American teachers view homework as an important part of mathematics learning, perhaps even more than their Chinese counterparts.

Item 40 is a question about the grade in which the use of a calculator for computation should start. Item 41 asks same question about the use of a computer-software. Significant group differences were found for these two items ($Z=5.986$, $p<0.001$ for item 40, and $Z=3.030$, $p<0.01$ for item 41). Fifty-four percent of American teachers selected elementary grades as the starting grade for use of a calculator, 41% selected junior high grades, only 5% selected senior high years. For the Chinese group, 20% selected elementary grades as a staring grade, 34% selected junior high grades and 46% selected senior high grades. A similar response pattern occurred on item 41.

Cluster 5: Teachers' Conception about Their Knowledge Structure

There are five questions involved in this cluster. Item 42 asked teachers about their mathematics ability in high school compared with their classmates. Significant group differences were found for this item ($Z=2.816$, $p<0.01$). Twenty percent of American teachers rated themselves as "*at the top 10%*", 17% rated themselves as "*above average*", 42% as "*about average*", and 11% as "*below average*". For the Chinese group, 36% of the teachers endorsed "*at the top 10%*", 37% endorsed "*above average*" and 26% endorsed "*about average*". No one in this group rated themselves as "*below average*".

Items 35, 36, and 37 asked teachers about their views on the importance of three kinds of knowledge -- *mathematics knowledge, knowledge about how to teach mathematics* and *knowledge about their students including how to motivate students to learn.* No significant

group differences were found for item 36 and 37. Most teachers in both groups agreed with the importance of knowledge about the teaching of mathematics and knowledge about understanding their students. There were, however, significant group differences in responses concerning the importance of mathematics subject knowledge (item 35, $Z=4.960$, $p<0.001$). Thirty-seven percent of American teachers endorsed "true", and 36% endorsed "somewhat true" of this item, whereas, 79% of Chinese teachers endorsed the item as "true" and 11% endorsed it as "somewhat true".

Item 43 asked teachers to rank the three kinds of knowledge by their level of importance. Group differences on this item were significant ($Z=4.458$, $p<0.001$ for knowledge about mathematics, $Z=2.842$, $p<0.01$ for knowledge about how to teach mathematics and $Z=4.693$, $p<0.001$ for knowledge about understanding students). The mean rank for the importance of mathematics knowledge for the American group was 1.66 ($S=0.80$) and that for the Chinese group was 2.30 ($S=0.76$). The mean rank for the importance of knowledge about how to teach mathematics for American teachers was 2.09 ($S=0.79$), whereas that ranking for the Chinese group was 2.47 ($S=0.68$). The Americans' mean rank for knowledge about the understanding of students was 2.27 ($S=0.76$), whereas for Chinese teachers, was 1.65 ($S=0.76$). American teachers place great value on knowledge of "understanding students" than on "how to teach mathematics", and ranked mathematics subject knowledge as least important. In contrast, Chinese teachers tended to believe that knowledge about how to teach mathematics and mathematics subject knowledge were more important than the knowledge of understanding students.

Summary

There were no significant group differences in the responses to the items concerning traditional views about the nature of mathematics. Teachers' conceptions of the nature of mathematics fall along an externally-internally developed continuum. However, significant group differences were found for modern constructive views.

Teachers' beliefs about the nature of mathematics as a course involved three components. Significant group differences were found for one of the three items (item 6) of the first component -- teachers' understanding of elementary mathematics. Items 9, 19, and 24 stated content similar to item 6, however, no significant group differences were found for these three items. Overall, it does not appear that there are significant group differences for this component. Group differences for two of three items of the second component, the purpose of learning elementary mathematics, were significant. Chinese teachers tend to believe that the purpose of learning elementary mathematics is to learn basic mathematics concepts and principles for further mathematics study. In contract, American teachers tended to think the purpose of this learning is for the solution of real world problems. Four out of seven items of the third component, which compared the characteristics of elementary mathematics with a language course, showed significant group differences. More American teachers agreed mathematics to be dry and that most of their students liked English better than mathematics, but only a few of the Chinese teachers concurred. However, more Chinese than American teachers believed there were more mathematically precocious children than reading precocious children in their school district.

For the third cluster, teachers' conception of mathematics teaching, there were no significant group differences found in the items of two components -- learner-focused view,

and content-focused view with an emphasis on conceptual understanding. Significant group differences were found in two of the four items of content-focused view with an emphasis on performance, and the item concerning a classroom-focused view. More Chinese teachers preferred well-structured and effectively-organized classroom activities, whereas more American teachers preferred "students' learning the right problem solving procedures through classroom practice and homework' and "showing students the exact way to answer mathematics questions on which they will be tested".

Significant group differences were found in all components of the fourth cluster, teachers' conceptions about mathematics learning. Three of four items on mathematics learning showed significant group differences. Most American teachers believed that mathematics geniuses could do well in mathematics without hard work, whereas many Chinese teachers did not. However, there were also more American than Chinese teachers who believed "there is no easy way to learn mathematics, the more you practiced, the more you accomplished". The responses to these two items were not consistent for the American group. Strong group differences were found for the item concerning parental involvement. Many American teachers wanted parents to work with their children on homework and projects, but most Chinese teachers did not. There were also significant group differences concerning the use of computational devices. More American teachers would allow their student to use calculators or computers to solve mathematics problems in elementary grades, while more Chinese teachers would allow their students to do so at the junior or senior level. Responses on homework assignment showed that more American teachers than Chinese teachers tended to assign homework in the first grade.

Analyses of items about mathematics teachers' knowledge structure revealed that American teachers tended to put knowledge about understanding of students as the first

priority, while mathematics subject knowledge was less valued. Chinese teachers tended to value mathematics knowledge and the knowledge of how to teach mathematics higher than knowledge of understanding students.

Discussion

The discussion is divided into five sections: personal discovery versus restricted instruction, solving real world problems versus laying a foundation for further learning, parental involvement, use of computational devices and beliefs about mathematics teachers knowledge structure.

Personal Discovery versus Restrict Instruction

Group differences in this study have shown that many American elementary mathematics teachers believe that teenagers are able to discover mathematics knowledge by themselves, but most Chinese teachers do not. Many Chinese teachers hold a positive view toward the classroom-focused model of mathematics instruction, whereas most American teachers do not. This kind of response pattern not only reflects cultural differences, but also parallels historical controversies of American education. Instructed learning has a long history in the United States. In the later half of the twentieth century, inspired by Sputnik and supported by theories of cognitive psychology, the reform of mathematics education in the United States adopted an approach of discovery learning which emphasized the training of creative thought and problem solving. Since then, American mathematics teachers have been bombarded with official reports and recommendations stressing this personal construct approach to mathematics (Dossey, 1992;

Ernest 1989a). The Curriculum and Evaluation Standards for School Mathematics proposed by National Council for Teachers of Mathematics (NCTM) in 1989 is an example of this thrust.

Although many American teachers accepted the modern constructivist view, the findings of this study have shown that many American teachers also hold a content-focused approach with an emphasis on performance. Thomas (1992) remarked about this approach: *"The content-performance view of teaching is analogous to what Brownell (1935) described as 'drill theory'. It is the view of teaching that would follow naturally from the instrumentalist view of the nature of mathematics"* (p. 136). According to Thomas, the philosophical beliefs about the nature of mathematics behind the content-performance approach to teaching are totally different from the modern constructivist view. However, the two views coexist in American elementary mathematics teachers' belief system. This may mean that cognitively many American elementary mathematics teachers have adopted the modern constructivist view as their philosophy about the nature of mathematics but, affectively, they prefer an instrumentalist view.

Historically, the instructed learning approach has been criticized by the advocators of discovery learning as "drill theory", meaningless, training of students' mechanical responses etc (e.g., Brownell, 1935). However, in the half of the century since the emergence of the personal construction approach to mathematics, we have not seen significant improvement in American students' mathematics. By contrast, international studies of mathematics education have consistently reported that the students from Asian countries, where the culture endorsed an instructed learning approach, have achieved at a higher level than American counterparts.

Two additional comments are warranted. First, teachers' philosophical beliefs about the nature of mathematics and their models of teaching mathematics are not clear and consistent.

For the current study, the taxonomy was based upon the extant literature rather than empirically derived. Clearly, the components of the taxonomy are not exclusive. Teachers may endorse more than one component of the taxonomy that appeared to be conflicting.

Second, the evaluation of a particular educational philosophy or a teaching model in our modern society tends to be global rather than an examination of its detailed components. For example, because the restricted-teaching model has been seriously criticized (e.g., Brownell, 1935, see above), the educational community rejected it. However, despite its shortcomings, there may be valuable characteristics of this model. One such characteristic might be the emphasis on teachers' guidance role. Specification of this role may motivate teachers to better prepare their lessons, and to seek better methods of instruction (An, 2000). An (2000) described a Chinese elementary mathematics teacher's preparation of instruction as follows:

> Mrs. Li spends 2-3 hours at school and one hour at home preparing for the next day's instruction. The sufficient planning time enables teachers to understand the subjects and their requirements fully, so they can prepare the instruction thoroughly. In the lesson plan, teachers write details about each sentence they are going to say to students from beginning of the class to the end, the step-by-step instruction of each problem, and the important parts and difficulties of the lesson. (p.4)

Discovery learning has also its advantages. However, it does not mean this model has no shortcoming. Without teachers' explicit instruction, students may spend excessive time in discovering for themselves mathematical rules. Thus, when assessing educational philosophies or teaching models, a complete component analysis may reveal strengths and weaknesses of

various approaches that would be missed by a simple conclusion about rightness or wrongness of the model.

Solving Real World Problem versus Laying a Foundation for Further Learning

An (2000) reported that the Chinese education system puts a strong emphasis on the basic concept and skill training. The Chinese culture views elementary education as a foundation for a comprehensive, solid and deeper understanding of basic knowledge rather than meeting immediate goals. Our interviews also suggested that Chinese teachers take a more extended and principle-based view of instruction. In contrast, American culture is pragmatic. "The goal of mathematics education is to solve real world problems" has been accepted and advocated by many American educators. These cultural differences may account for group differences in responses to the items about the purpose of elementary mathematics education.

While we agree that a purpose of learning is to solve real world problems, the meaning of this phrase regarding mathematics instruction is not clear. The relative level of difficulty of application is not revealed in this phrase. Both successful shopping and the space vehicle design use mathematics to solve practical problems. For an elementary school child, *being able to shop* is a proximal and attainable goal, *designing a workable space vehicle* is a distal and challenging goal; *laying a strong mathematical foundation* is also a distal goal. Manderlink and Harackiewicz (1984) suggested that proximal and distal goals affect the performance differently. Conceptions of self-efficacy were more positively affected by proximal goals than distal goals, particularly during task engagement. However, intrinsic motivation was positively affected by distal goals rather than proximal goals (p. 925). Locke et al (1980) have reported that specific challenging goals led to greater output than vague or easy goals.

Although laying-a-foundation does not sound like a specific goal, and the solving-real-world-problem does not seem a clear goal, the belief holders may endow them with meanings that make them specific and clear. In our interviews, Chinese teachers reported that their meanings of *lay-a-foundation* involved understanding basic knowledge deeply and solidly and executing basic skills precisely and fluently. They stated that the Central Department of Education of China has specified in detail the basic mathematics knowledge and skills for each grade in the National Standards of Teaching Mathematics. For Chinese teachers, *laying-a-foundation* is both a distal and proximal goal. At this time, we do not know whether American teachers conceptualize the goal of *solving-real-world-problems* as a proximal goal, a distal goal, or both.

Learning mathematics is a very sequential building process. Setting the purpose for mathematics instruction as laying-a-foundation may lead the Chinese teachers to recognize the connection between their present teachings and their students' future learning. Ma (1999) reported that the Chinese mathematics teachers study the connections among mathematics topics. They plan instruction to address current content and to build a conceptual understanding for further learning. Stigler and his colleagues (1999) have reported on the lesson pattern differences between the United States and Germany versus Japan. In the American/German classrooms, students were expected to learn how to solve particular types of problems. In Japanese classrooms, problem solving is not the goal of the lesson rather it is the means through which students are to obtain knowledge of mathematics. As the Japanese, the Chinese embrace a similar educational philosophy and believe in similar teaching models. Thus, differences in lesson plans may reflect the differences in teachers' beliefs about the purpose of mathematics education.

Parental Involvement

It is interesting that most Chinese elementary mathematics teachers do not like parental involvement in their students' completion of homework and projects. Currently, the reasons behind this finding are unknown. While, the restricted model of instruction is commonly criticized as a spoon-fed education model, this finding suggests that the Chinese teachers, who adopted the restricted teaching model, expected their students to complete the assignments independently. In the United States, while individual discovery has been advocated for a long time, many American teachers believe that without parents' help students are not able to excel at mathematics.

Uses of Computational Devices

Many American teachers agreed with early use of computational devices in the elementary grades. This result parallels the finding from the 1993 survey conducted by the Public Agenda Foundation, a New York-based nonprofit, nonpartisan education and research organization. According to the Public Agenda Foundation's study, American educators overwhelmingly view the early use of calculators positively. About 82% of respondents thought that *"early use of calculators will improve children's problem solving skills and not prevent the learning of arithmetic"*, while only 12% of them were worried that *"early use of calculators in elementary school grades can hamper"* children's learning of mathematics skills (p. 2). In the United States, the early use of calculators in elementary grades is advocated by official documents, such as 1989 Curriculum and Evaluation Standards for School Mathematics of NCTM. Although there is no specific rule limiting the use of calculators in Chinese schools, many Chinese mathematics teachers do not encourage their students to use these devices in the lower grades. One possible reason for this approach may be the influence of the college

admission test. In China, the use of a calculator in college admission tests is prohibited. Early use of computational devices continues to be an issue in contemporary mathematics education. A recent study (Campbell & Xue, 2001) reported that the calculator use was negatively correlated with students' performances on more complex multi-step arithmetic. In the current study, 54% of American teachers agreed with the use of calculators in elementary grades. This is 28% lower than that of the Public Agenda Foundation's finding. Since our data were collected seven years later after the Public Agenda Foundation's study, this could indicate there is a growing disagreement about early use of calculators by American elementary mathematics teachers.

Beliefs about Elementary Mathematics Teachers' Knowledge Structure

In this study, American teachers' self-ratings of their mathematics ability in high school were lower than those of Chinese teachers. The findings also indicated that American elementary mathematics teachers tended to believe that knowledge about the understanding of students was the most important contributor to being a good mathematics teacher, followed by knowledge of how to teach elementary mathematics and mathematics subject knowledge. Chinese teachers valued mathematics subject knowledge and the knowledge of how to teach elementary mathematics but placed less value on knowledge of understanding students. Shalman (1986) suggests that pedagogical content knowledge is highly specific to a particular subject matter, and learning to teach requires both understanding the subject knowledge and developing a wide repertoire of pedagogical content knowledge. Teachers' thorough subject knowledge enables them to develop the understanding of their students through well-organized instruction, appropriate tasks, explanations and demonstrations. Also teachers' wide pedagogical knowledge enables them to help learners from different backgrounds. Ma (1999)

remarked on American mathematics teachers' attitude toward mathematics subject knowledge: "Compared with subject matter knowledge, other aspects of teaching usually receive more attention" (p. 26). She pointed out, the quality of particular teaching methods used for a specific mathematics topic relies on the quality of teachers' subject matter knowledge. Thus, it appears important to draw the attention of educational policy makers and the leaders of teachers' training programs to help mathematics teachers to more highly value mathematics subject knowledge.

Final Remarks

This is an exploratory study. Its primary merit is that it provides various information about cultural differences between American and Chinese elementary mathematics teachers' beliefs about mathematics and mathematics teaching. Thus, it may be a resource for educational policy makers and educational researchers in their further studies.

Appendix

Survey about Mathematics Teachers' Beliefs of Mathematics and Mathematics Teaching

Items 1 to 37 are likert-type items. Each item has four choices: "true", "somewhat true", "somewhat false" and "false".

1. All the mathematical principles, theorems and axioms are absolute truths. They existed in the universe. The mathematicians' job is to discover them.
2. Like all other kinds of knowledge, the mathematics knowledge develops through a process of accumulating mathematicians' observation, experimentation and abstraction.

3. The mathematicians' experiences and their personal philosophy may affect the process of forming mathematical knowledge.
4. The mathematics we learned in elementary and secondary school is mostly facts and procedures that have to be memorized.
5. The mathematics we learned in elementary and secondary school is mostly skills, such as computation, number and symbol manipulation, space manipulation, and so on, which can be learned mainly through doing.
6. The mathematics we learned in elementary and secondary school is mostly conceptions, principles, and theorems, which can be learned mainly through logical thinking and reasoning.
7. Unlike reading comprehension, the mathematics problems in elementary and secondary mathematics classrooms have only one true answer.
8. Mathematics is a useful tool for scientific studies however elementary mathematics is not much use in scientific studies. The purpose of elementary mathematics is learning basic mathematics concepts, principles and skills for further mathematics study.
9. Mathematics is a kind of mental exercise. The goal of elementary mathematics learning is to train logical thinking and reasoning.
10. The purpose of elementary mathematics teaching is to teach pupils to solve real world problems.
11. English teaching emphasizes training in comprehension, expression, compassion and affection.
12. Mathematics teaching emphasizes the training in organization, computation, logical reasoning, and abstract thinking.

13. Compared to English, mathematics is dry. Most of my students like English more than mathematics.
14. I think mathematics is a more difficult subject for my students than is English.
15. There are more mathematically precocious children than reading precocious children in my school district.
16. There are many open-ended questions in elementary mathematics.
17. As an elementary mathematics teacher, my job is to demonstrate, explain and define the material, present the material in an expository style, and then ask students to do problems using the rules that have been learned.
18. As an elementary school mathematics teacher, my role in the classroom is as a facilitator and stimulator of student learning by posing interesting questions and situations for investigation, challenging students to think, and by helping them uncover inadequacies in their own thinking.
19. As an elementary mathematics teacher, I demonstrate, explain, and define the material, but would like to emphasize students' understanding of the logical relations among various mathematical ideas and concepts.
20. I think the most important thing for the elementary mathematics teachers is that classroom activity must be well structured and effectively organized.
21. Good elementary mathematics teachers ask students to memorize the right problem solving procedures.
22. Good elementary mathematics teachers ask students to learn the right problem solving procedures through classroom practice and homework.

23. Good elementary mathematics teachers give students mathematics problems and motivate students to discover the right answers by themselves (or in a group) in class time.
24. Good elementary mathematics teachers emphasize training of logical thinking and reasoning.
25. Good elementary mathematics teachers show students the exact way to answer mathematics questions on which they will be tested.
26. Good elementary mathematics teachers show students lots of different ways to answer the same mathematics question.
27. Teenagers can discover (or create) something of mathematics by themselves.
28. Real mathematics problems can be solved by common sense instead of mathematics rules you've learned in school.
29. The best way to learn mathematics is to memorize all the mathematics formulas.
30. To solve mathematics problems, you have to be taught the right procedures or you can do nothing.
31. Mathematics is an easy class for some children, but a hard class for others. I think there are mathematics geniuses who can do well in mathematics without hard work.
32. There is no easy way to learn mathematics. The more you practiced, the more you accomplished.
33. Children's mathematics achievement is related to parents' contribution. If parents work with their children on mathematics homework and projects, their children could achieve higher marks in mathematics.
34. Usually, well-educated parents have mathematics talented children.
35. In order to be a good elementary mathematics teacher, I need to learn more mathematics.

36. In order to be a good elementary mathematics teacher, I need to learn more about how to teach mathematics.

37. In order to be a good elementary mathematics teacher, I need to learn more about my students (such as their cognitive style, interests, and so on) and how to motivate them to learn.

38. For daily mathematics homework assignments, how much time do you think is adequate? (Circle one)

(a) None (b) less than 10 minutes (c) 10-20 minutes

(d) 20-30 minutes (e) More than 30 minutes

39. I think pupils should have homework assignments starting from

(a) Grade 1 (b) Grade 2 (c) Grade 3

(d) Grade 4 (e) Grade 5 (f) Grade 6

40. I would allow my students to use a calculator to do mathematics computation instead of using hand and mental calculation, starting from _____.

(a) Grade 3 (b) Grade 4 (c) Grade 5

(d) Grade 6 (e) Junior high (f) Senior high

41. I would allow my students to use a computer software to solve mathematics problems, starting from _____.

(a) Grade 5 (b) Grade 6 (c) Junior high

(d) Senior high (e) College

42. Compared with my high school classmates, my mathematics ability in high school was

(a) in the top 10% (b) above average (c) about average

(d) below average (e) in the bottom 10%

43. There are three kinds of knowledge about which mathematics teachers may have, knowledge about mathematics, knowledge about how to teach mathematics and knowledge about understanding students. Which one do you think is more important? Please rank them. (3 points for the most important, 2 points for the second most important and 1 point for the less important).

Kind of knowledge	Rank
Knowledge about mathematics	
Knowledge about how to teach mathematics	
Knowledge about understanding students	

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Table 1
Organization of measurement instrument
(The survey consists of five clusters, composed of varying numbers of components, with each component having its items)

Cluster	Item Number
1. The nature of mathematics as a subject	
a. External perspective	1
b. Internal perspective	2-3
c. Modern constructivism view which have not been covered by "b"	27-28
2. The nature of elementary mathematics (as a course)	
a. What is elementary mathematics	4-6
b. The purpose of learning elementary mathematics	8-10
c. The characteristics of elementary math (compared with English or Chinese)	7, 11-16
3. Teachers conceptions of math teaching	
a. Content focused view with an emphasis on performance	17, 21, 22, 25
b. Learner focused view	18, 23
c. Content focused view with an emphasis on conceptual understanding	19, 24, 26
d. Classroom focused view	20
4. Teachers' conceptions about mathematics learning	
a. Math learning	29-32
b. Homework assignment	38-39
c. Use of computational devices	40-41
d. The relationship between parental factors with children's achievement	33-34
5. Teacher's conceptions about their knowledge structure	35-37, 42-43

Table 2

Percent of reviewers' agreement about item objective, item-cluster correlation, item-total correlation for each item

Item	Percent of reviewer's agreement	Item-cluster correlation	Item-total correlation
1	100%	.461**	.259**
2	100%	.443**	.338**
3	80%	.556**	.315**
27	100%	.606**	.143
28	100%	.521**	.219**
4	60%	.270**	.301**
5	80%	.376**	.330**
6	80%	.579**	.427**
7	80%	.372**	.265**
8	80%	.444**	.270**
9	100%	.455**	.345**
10	100%	.195*	.265**
11	100%	.478**	.231**
12	60%	.369**	.280**
13	80%	.333**	.276**
14	80%	.448**	.346**
15	60%	.421**	.220**
16	80%	.352**	.124
17	100%	.521**	.453**
18	80%	.339**	.270**
19	60%	.459**	.323**
20	100%	.479**	.452**
21	100%	.552**	.398**
22	60%	.644**	.321**
23	60%	.420**	.466**
24	80%	.316**	.284**
25	100%	.397**	.352**
26	60%	.249**	.145
29	100%	.562**	.343**
30	100%	.596**	.381**
31	100%	.728**	.347**
32	100%	.617**	.336**
33	100%	.775**	.379**
34	100%	.598**	.454**
35	100%	.871**	.147
36	100%	.728**	.249**
37	100%	.554**	.095

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 3

Correlations between clusters and total scores, and the correlations among the clusters

	Subject	Course	Teaching	Learning	Knowledge
Nature of math as a subject	1.000				
Nature of math as a course	.307**	1.000			
Conceptions of teaching	.120	.292**	1.000		
Conceptions of learning	.220**	.074	.326**	1.000	
Knowledge structure	-.038	.164*	.049	-.036	1.000
Total score	.490**	.719**	.735**	.573**	.215**

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

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